REMARKS

The specification has been amended in the same manner as in parent application Serial No. 09/532,818, of which the present application is a Division.

The title has been amended to correct the spelling of the word "CONFOCAL" therein.

Claims 1-7 have been canceled, without prejudice.

The present application is a Division, and is directed to the subject matter of claims 8-14 of the original application.

Submitted concurrently herewith is an Information Disclosure Statement. It is respectfully requested that the Examiner act thereon and make the references identified therein "of record".

Submitted herewith is a Letter to the Official Draftsperson providing corrected drawings. The drawing corrections are the same as made in the parent application.

It is respectfully requested that prosecution on the merits now proceed on the basis of the application as amended hereinabove.

If the Examiner has any comments, questions, objections or recommendations, the Examiner is invited to telephone the undersigned at the telephone number given below for prompt action.

Respectfully submitted,

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MARKED UP VERSION OF SPECIFICATION SHOWING CHANGES MADE THERETO

COPY

COPY

already amended in Preliminary Amendment

TITLE OF THE INVENTION

CONFOCAL

~~CONFORCAL~~ MICROSCOPE

This is a DIVISION of Application Serial Number 09/532,818 filed March 21, 2000.

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims the benefit of priority from the prior Japanese Patent Applications No. 11-078281, filed March 23, 1999; No. 11-080026, filed March 24, 1999; No. 11-080028, filed March 24, 1999; and No. 11-080202, filed March 24, 1999, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

This invention relates to a confocal microscope adapted to observe and measure the micro-structure and the three-dimensional profile of a specimen by utilizing light.

Known typical confocal microscopes adapted to operate at high speed include those comprising a Nipkow's disk having a large number of pin holes arranged helically at intervals about ten times as large as their diameter. A confocal microscope comprising ~~a~~ Nipkow's disk is required to eliminate cross talk arising from adjacently located pin holes, and hence relatively large intervals have to be used ~~in~~ order to separate the pin holes from each other. The large intervals reduce the efficiency of utilizing the beam of light from the light source and, as a matter of fact, only 1% of the beam coming from the light source

a non-confocal image.

FIG. 5B is an enlarged schematic partial plan view of the rotary disk of FIG. 5A, illustrating the random pin hole pattern section 36b of the disk in greater detail. As shown in FIG. 5B, the section 36b has a plurality of pin holes 36a that allow light to pass therethrough and a shield mask 36f, which occupies the area other than the pin holes 36a and is formed typically by depositing Cr by evaporation so as not to allow any light to pass therethrough. The half-diameter r of the pin holes 36a is normally so selected as to be expressed by formula (1) below:

$$r = bM\lambda/NA \qquad \cdots (1),$$

where M ~~is~~ represents the magnification of the sample image projected on the disk ~~lens~~, NA is the aperture ratio, λ is the wavelength of light and b is a constant which is about 0.35. Therefore, if the wavelength λ is equal to 550 nm, the magnification M is 100 and NA = 0.9, the half-diameter r of the pin holes will be 21.4 μm.

If the area of the random pin hole pattern section 36b having a profile of a sector is S_0 and the total area of the plurality of light-transmitting pin holes is S_1, the transmissivity k of the sector-shaped random pin hole section 36b is expressed by formula (2) below.

$$k = S_1/S_0 \qquad \cdots (2)$$

Assume that the brightness data of point (x,y) of a conventional image of an ordinary microscope is

the obtained image contains only the legible component in the B direction and hence the confocal component is equal to "0". On the other hand, arrow A in FIG. 7B is perpendicular to the linear light transmitting areas. Therefore, the confocal component is maximal an the legible component is minimal in the obtained image.

Thus, when a rotary disk having linear light transmitting areas (slits) is used, the ratio of the confocal component to the legible component varies as a function of the direction of the light blocking areas relative to the picked up image.

Therefore, as the longitudinal direction of the light blocking areas is turned by 90° , the confocal component and the non-confocal component are equalized in different directions and hence the image obtained by means of a sector-shaped linear pattern section 62a having a central angle of 90° is a composite image obtained by adding a non-confocal image to a confocal image as in the case of the first embodiment. Thus, the confocal image can be obtained by subtracting, using the CPU 52, the conventional image, which is the non-confocal image, obtained by means of the aperture section 62b from the composite image.

Additionally, since the transmissivity of the linear pattern section 62a is 1/2 and the area of the aperture section 62b is 1/4 of that of the linear pattern section ~~60a~~ 62a, the confocal image can be obtained

a non-confocal image.

If the image data of the composite image corresponding to pixel position (x,y) of the image pickup device of the CCD camera 46 is $cm_{(x,y)}$ and the image data corresponding to the conventional image is $m_{(x,y)}$, the image data $c_{(x,y)}$ of the confocal image for the position (x,y) can be obtained by formula (8) below.

$$c_{(x,y)} = cm_{(x,y)} - m_{(x,y)} \qquad \cdots (8)$$

A confocal image can be obtained by carrying out the arithmetic operation of formula (8) above for all the pixels.

Meanwhile, the ratio of the brightness of the composite image to that of the conventional image is determined by the ratio of the area of the linear pattern section 64a and that of the aperture section 64b. The non-confocal component of a composite image can be eliminated only by equalizing the brightness of the conventional image and that of the non-confocal component of the composite ~~it~~ image. If they show different levels of brightness, the non-confocal image component can be left in the outcome of the subtraction or the confocal image can be subtracted and missed.

In view of the above circumstances, the conventional image data is multiplied by a constant by means of the constant program 66b and then the composite image data is subjected to an operation of subtracting

therefrom the data of the corresponding position of the conventional image obtained by the above multiplication using a constant by the subtraction program 66a in order to computationally obtain the confocal image in order to make the brightness of the non-confocal image component of the composite image equal to that of the conventional image in the third embodiment.

The outcome of the subtraction is displayed on the display screen of the monitor 58. Thus, the user can regulate and modify the obtained image by modifying the constant stored in the constant program 66b by visually confirming the outcome of the subtraction on the monitor 58 and also the confocal effect (the state where the defocused component of the image is eliminated from the displayed image) generally by shifting the focal point.

This operation will be discussed in greater detail by referring to the flow chart of FIG. 10.

Firstly, in Step S1, coefficient α to be used for subtracting the conventional image (non-confocal image) data obtained by means of the aperture section 64b from the composite image data obtained by means of the linear pattern section 64a is input. While the coefficient α may vary depending on the transmissivity of the linear pattern section 64a, the ratio of the area of the linear pattern section ~~64~~ 64a and the aperture section 64b, the magnification of the objective

FIG. 12B is a schematic cross sectional lateral view of the rotary disk 70 to which the shield plates 70_1 and 70_2 are fitted. As may be seen from FIG. 12B, each of the light blocking sections 70d, 70e is provided with a pair of shield plates 70_1 and 70_2, only one of the two pairs of shield plates is shown because they are identical and symmetrically arranged.

The shield plates 70_1 and 70_2 are fitted to the rotary disk 70 by means of the holes arranged at the top thereof and shield plate holding members 72a, 72b. The shield plates ~~70b~~ 70_1 and 70_2 are ~~is~~ provided at the center thereof with a through hole for allowing the rotary shaft to pass therethrough. Additionally, the shield plate ~~70a~~ 70_1 is provided at the outer periphery thereof with screw threads, whereas the shield plate ~~70b~~ 70_2 is provided at the inner periphery thereof with screw threads. Thus, the shield plates 70_1 and 70_2 can be rigidly held in position by tightening a screw (not shown).

The area of the light blocking sections 70d, 70e can be modified by loosening the screw rigidly holding the shield plate holding members 72a, 72b and moving the shield plates 70_1 and 70_2 around the rotary shaft to modify the area of the aperture section 70c and that of the random pin hole pattern section 70b. Then, the shield plate holding members 72a, 72b are made to be rigidly held in position by tightening the screw so that the shield plates 70_1 and 70_2 may become immobile

ABSTRACT OF THE DISCLOSURE

In a confocal microscope, ~~according to the invention, the~~ a beam of light from a light source is lead to a rotary disk by way of an optical lens and a half mirror, and made to strike specimen by way of an objective lens. The rotary disk has random pin hole pattern sections where pin holes are randomly bored through a light blocking mask, and an aperture section having an area k^2 times greater than the area of the random pin hole pattern sections and allowing any light to pass therethrough. The beam of light reflected by the specimen is made to enter a CCD camera by way of the objective lens, the rotary disk, the half mirror and a condenser lens. The CCD camera is adapted to selectively pick up a composite image containing a confocal image component and a non-confocal image component of the specimen obtained through the random pin hole pattern sections and a conventional image of the specimen obtained through the aperture section. Then, a CPU carries out an arithmetic operation of subtracting the conventional image data from the composite image data by means of a difference program to produce a confocal image of the specimen.